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(54) [Title of the Invention] Correcting Method for Recording Pulse in Mark Edge Recording System

(57) [Abstract]

[Object] An object of the present invention is to provide a mark edge recording system in which mark edge positions can be controlled accurately even with ambient environmental changes or the like.

[Constitution] When edge positions are controlled, a CPU writes initial correction values of a pulse width and an output timing of a recording pulse

into a memory. A recording pulse of designated data is actually written and recorded onto an optical recording medium based on the correction values that are stored in this memory. Subsequently, the recorded data is reproduced and this reproduction data is compared with the designated data. The correction values are changed and written again into the memory, and writing/recording onto the optical recording medium based on these correction values and reproduction/comparison of the data are repeated until both data match each other. The present invention is provided with a learning function with which the optimum correction values are determined and set through the above procedure, which is capable of adapting itself to changes of types and characteristics of the optical recording medium at that time, changes in the ambient environment, and changes over time of a driving device and the medium itself, so that the edge positions can be controlled accurately.

[Scope of Patent Claims]

[Claim 1] A recording pulse correcting method for a mark edge recording system,

wherein an optical recording medium is irradiated with laser light whose intensity is modulated; and

wherein information is recorded by forming recording marks whose length holds information;

a recording pulse correcting method being characterized in that a CPU writes initial correction values of a pulse width and an output timing of a recording pulse into a memory;

a recording pulse of designated data is written and recorded onto the optical recording medium based on the correction values that are stored in the memory, after which the recorded data is reproduced;

the reproduction data is compared with the designated data; and

the correction values are repeatedly changed and written into the

memory, written/recorded onto the optical recording medium based on the correction values, and reproduced/compared until both data match each other, so that optimum correction values are determined and set.

[Claim 2] The recording pulse correcting method for the mark edge recording system according to claim 1,

wherein after the reproduction data matches the designated data, the recorded data is reproduced again while shifting a phase of a reproducing system data PLL by a predetermined amount;

wherein the reproduction data is compared with the designated data;

wherein until both data match each other, the correction values are again repeatedly changed and written into the memory, written/recorded onto the optical recording medium based on the correction values, and reproduced/compared; and

wherein after both data match each other, the correction values are repeatedly reproduced/compared while shifting the phase, so that optimum correction values are determined and set.

[Claim 3] The recording pulse correcting method for the mark edge recording system according to claim 1 or 2,

wherein the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance; and

wherein the initial correction values of the recording pulse are written from the designated region of the optical recording medium into the memory.

[Claim 4] The recording pulse correcting method for the mark edge recording system according to claim 3,

wherein the determined optimum correction values are recorded onto the designated region of the optical recording medium over the initial values that are stored at that time; and

wherein the determined optimum correction values serve as initial

values in a next leaning operation of correction values.

[Claim 5] The recording pulse correcting method for the mark edge recording system according to claim 1, 2, 3 or 4,

wherein the correction values of the recording pulse include not only correction values of a pulse width and an output timing of the recording pulse, but also correction values of recording power at a leading portion of the recording pulse and a time during which this recording power is changed.

[Claim 6] The recording pulse correcting method for the mark edge recording system according to claim 1, 2, or 3,

wherein when recording the designated data or actual data, a recording pulse length L_0 that is to be written, a blank length L_1 right before this recording pulse, and a recording pulse length L_2 before this blank are determined by a data pattern identification means;

wherein data of the length values L_0, L_1, and L2 are taken as the address input of the memory; and

wherein an output from the memory serves as correction values of the recording pulse.

[Claim 7] The recording pulse correcting method for the mark edge recording system according to claim 6,

wherein a pulse indicating front and rear edge positions of a recorded data pattern is delayed by a delaying means based on the correction values of the recording pulse that is read out from the memory; and

wherein from the delayed pulse trains, recording pulses in NRZI code are formed.

[Claim 8] The recording pulse correcting method for the mark edge recording system according to claim 6,

wherein a pulse indicating a front edge position of a recorded data pattern and a pulse indicating a rear edge position thereof are separated by a pulse train separating means;

wherein the separated pulse trains are delayed by a delaying means

based on the correction values of the recording pulse that is read out from the memory; and

wherein from the delayed pulse trains, recording pulses in NRZI code are formed.

[Claim 9] The recording pulse correcting method for the mark edge recording system according to claim 1 or 2,

wherein random data of a modulated code that is used serves as the designated data.

[Claim 10] The recording pulse correcting method for the mark edge recording system according to claim 6,

wherein a displacement amount of an edge of a reproducing pulse signal from a center of a data identification window is detected by an edge displacement amount detecting means; and

wherein when this displacement amount is equal to a predetermined amount or more, the correction values are changed by an amount corresponding to this displacement amount, and are written again into the memory, so that optimum correction values are determined and set.

[Claim 11] The recording pulse correcting method for the mark edge recording system according to claim 10,

wherein a plurality of discriminators are used as the edge displacement amount detecting means;

wherein a plurality of reproducing pulse signals are reproduced using a window shifted constantly by a predetermined amount as a data identification window corresponding to these discriminators; and

wherein a verify check is performed on the signals, so that the displacement amount from the center of the data identification window is detected.

[Claim 12] The recording pulse correcting method for the mark edge recording system according to claim 10,

wherein one discriminator is used as the edge displacement amount

detecting means;

wherein designated data in which data with the same pattern is repeated is recorded;

wherein during reproduction, the data is reproduced while the data identification window is constantly shifted by a predetermined amount; and

wherein a verify check is performed on the data, so that the displacement amount from the center of the data identification window is detected.

[Claim 13] The recording pulse correcting method for the mark edge recording system according to claim 10,

wherein a phase comparator is used as the edge displacement amount detecting means.

[Claim 14] The recording pulse correcting method for the mark edge recording system according to claim 10,

wherein the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance;

wherein the initial correction values of the recording pulse are written from the designated region of the optical recording medium into the memory;

wherein determined optimum correction values are written over the initial values that are stored in the designated region of the optical recording medium at that time; and

wherein the determined optimum correction values serve as initial values in a next learning operation of correction values.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application] The present invention relates to a recording pulse correcting method for the mark edge recording system for an

optical disk driving device or a magneto-optical disk driving device.

[0002]

[Prior Art] Generally, when data is written onto optical disks, the optical recording medium is irradiated with laser light and is heated, and thus pits are formed on the medium, a magnetization direction of the medium is reversed, or a crystalline state of the medium is changed, so that the data is recorded.

[0003] As one of the recording methods for optical disks, there is a "mark edge recording method" in which front and rear edges of a recording mark respectively correspond to codeword bits, so that a recording mark length holds information. While this recording method is suitable for higher density recording, the edge positions are required to be accurate.

[0004] That is to say, when recording is performed using the mark edge recording method, an actually recorded mark may be longer than the applied recording pulse because of remaining heat of the directly preceding recording mark, or the mark shape may be irregular as shown in FIG. 17, since heat of laser light is not accumulated sufficiently in the vicinity of the front edge. Therefore, the edge positions are shifted with respect to the ideal positions, jitter increases, and in the worst case, it becomes impossible to reproduce the original data. Thus, the mark edge positions need to be controlled accurately in the mark edge recording method.

[0005] For this reason, JP S63-53722A discloses an edge position control method in which a pulse width and power of a recording light pulse are corrected in accordance with the recording radius of the optical disk, or the recorded data pattern density (that is, the length of its directly preceding blank).

[0006]

[Problems to be Solved by the Invention] However, when recording onto a medium whose thermal conductivity is high, such as a magneto-optical

disk, front and rear edge positions of a recording mark are shifted because of not only the heat of the recording mark that is being written, but also the remaining heat of the recording mark that was written right before. More specifically, the amount of the remaining heat that is accumulated in the optical disk differs depending on the length of the directly preceding mark or blank. Therefore, the edge displacement amount changes depending on the recorded data pattern. One example is shown in FIG. 18, as a pattern a and a pattern b. Although their blank lengths are the same, their recording pulse lengths right before the blanks are different, so that the heat accumulation amount on the optical disks is different between the disks, and the edge displacement amount is different between their recording marks. For this reason, when recording onto a magneto-optical disk, the edge positions cannot be controlled accurately by conventional methods, such as setting a constant correcting amount of a pulse width and power of a recording pulse, or determining a correcting amount depending only on the directly preceding blank length.

[0007] Furthermore, when correcting the above-described irregular mark shapes, from reasons similar to the above, a degree of non-uniformity of the mark shape varies depending on the recorded data pattern, so that the mark shape is not corrected sufficiently by conventional methods, such as setting the leading portion in a recording pulse to a constant power, or determining the power depending only on the directly preceding blank length.

[0008]

[Means for Solving the Problems] According to the invention described in claim 1, in a recording pulse correcting method for a mark edge recording system, an optical recording medium is irradiated with laser light whose intensity is modulated, and information is recorded by forming recording marks whose length holds information. A CPU writes initial correction values of a pulse width and an output timing of a recording pulse into a

memory. A recording pulse of designated data is written and recorded onto the optical recording medium based on the correction values that are stored in the memory, after which the recorded data is reproduced. The reproduction data is compared with the designated data. The correction values are repeatedly changed and written into the memory, written/recorded onto the optical recording medium based on the correction values, and reproduced/compared until both data match each other, so that optimum correction values are determined and set.

[0009] In addition to the above, according to the invention described in claim 2, after the reproduction data matches the designated data, the recorded data is reproduced again while shifting a phase of a reproducing system data PLL by a predetermined amount. The reproduction data is compared with the designated data. Until both data match each other, the correction values are again repeatedly changed and written into the memory, written/recorded onto the optical recording medium based on the correction values, and reproduced/compared. After both data match each other, the correction values are repeatedly reproduced/compared while shifting the phase, so that optimum correction values are determined and set.

[0010] Among these inventions, according to the invention described in claim 3, the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance. The initial correction values of the recording pulse are written from the designated region of the optical recording medium into the memory.

[0011] According to the invention described in claim 4, the determined optimum correction values are recorded onto the designated region of the optical recording medium over the initial values that are stored at that time. The determined optimum correction values serve as initial values in a next leaning operation of correction values.

[0012] Furthermore, according to the invention described in claim 5, the correction values of the recording pulse include not only correction values of

a pulse width and an output timing of the recording pulse, but also correction values of recording power at a leading portion of the recording pulse and a time during which this recording power is changed.

[0013] On the other hand, according to the invention described in claim 6, when recording the designated data or actual data, a recording pulse length L_0 that is to be written, a blank length L_1 right before this recording pulse, and a recording pulse length L_2 before this blank are determined by a data pattern identification means. Data of the length values L_0, L_1, and L2 are taken as the address input of the memory. An output from the memory serves as correction values of the recording pulse.

[0014] In addition to the above, according to the invention described in claim 7, a pulse indicating front and rear edge positions of a recorded data pattern is delayed by a delaying means based on the correction values of the recording pulse that is read out from the memory. From the delayed pulse trains, recording pulses in NRZI code are formed.

[0015] Similarly, according to the invention described in claim 8, a pulse indicating a front edge position of a recorded data pattern and a pulse indicating a rear edge position thereof are separated by a pulse train separating means. The separated pulse trains are delayed by a delaying means based on the correction values of the recording pulse that is read out from the memory. From the delayed pulse trains, recording pulses in NRZI code are formed.

[0016] Furthermore, according to the invention described in claim 9, random data of a modulated code that is used serves as the designated data.

[0017] According to the invention described in claim 10, in addition to the invention described in claim 6, a displacement amount of an edge of a reproducing pulse signal from a center of a data identification window is detected by an edge displacement amount detecting means. When this displacement amount is equal to a predetermined amount or more, the correction values are changed by an amount corresponding to this

displacement amount, and are written again into the memory, so that optimum correction values are determined and set.

[0018] At that time, according to the invention described in claim 11, a plurality of discriminators are used as the edge displacement amount detecting means. A plurality of reproducing pulse signals are reproduced using a window shifted constantly by a predetermined amount as a data identification window corresponding to these discriminators. A verify check is performed on the signals, so that the displacement amount from the center of the data identification window is detected.

[0019] Furthermore, according to the invention described in claim 12, one discriminator is used as the edge displacement amount detecting means. Designated data in which data with the same pattern is repeated is recorded. During reproduction, the data is reproduced while the data identification window is constantly shifted by a predetermined amount. A verify check is performed on the data, so that the displacement amount from the center of the data identification window is detected.

[0020] Furthermore, according to the invention described in claim 13, a phase comparator is used as the edge displacement amount detecting means.

[0021] Furthermore, the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance. The initial correction values of the recording pulse are written from the designated region of the optical recording medium into the memory. Determined optimum correction values are written over the initial values that are stored in the designated region of the optical recording medium at that time. The determined optimum correction values serve as initial values in a next learning operation of correction values.

[0022]

[Effect] According to the invention described in claim 1, data is actually written and recorded based on the designated data, and is reproduced.

Until this reproduction data matches the initial designated data, the correction values of the recording pulse are changed, and thus, optimum values are determined and set. Due to this learning function, the edge position control can be performed appropriately, so that it is possible to accommodate changes in the type or the characteristics of the optical recording medium, changes in the ambient environment, and changes over time of a driving device or the medium itself.

[0023] In addition to the above, according to the invention described in claim 2, after the reproduction data matches the designated data, reproduction data of the recorded data is repeatedly compared with the designated data in a similar manner, while shifting a phase of a reproducing system data PLL, until both data match each other. Therefore, it becomes possible to correct the front and rear edges of the recording pulse so that they are positioned at the center of the data identification window that is formed by the reproducing system data PLL. Thus, data can be reproduced without an data error even when the phase of the reproducing system data PLL is shifted.

[0024] According to the invention described in claim 3, the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium. Therefore, it is not necessary to store the correction values in a control system on which the CPU is mounted, so that the memory capacity in the control system can be smaller. Furthermore, since it becomes possible to use the initial correction values that are suitable for individual optical recording media, the learning operation time can be shortened.

[0025] According to the invention described in claim 4, the optimum correction values that are determined by the learning function are recorded onto a designated region of the optical recording medium, and are used as initial values in a next leaning operation of correction values. Therefore, the learning operation time can be shortened in the next recording.

[0026] According to the invention described in claim 5, the correction values of the recording pulse include not only correction values of a pulse width and an output timing of the recording pulse, but also correction values of recording power at a leading portion of the recording pulse and a time during which this recording power is changed. Therefore, the edge positions and the mark shape of the recording marks can be controlled accurately so as to meet various conditions of the optical recording medium at that time.

[0027] According to the invention described in claim 6, a recording pulse length L_0 that is to be written, a blank length L_1 right before this recording pulse, and a recording pulse length L_2 before this blank are determined, are taken as the address input of the memory, and an output from the memory is used as correction values of the recording pulse. Therefore, the correction can be used for recorded data patterns, in addition to changes of types of the optical recording medium, changes in the ambient environment, and changes over time of a driving device and the medium itself, so that the edge positions can be controlled further accurately.

[0028] According to the invention described in claim 7, a pulse indicating front and rear edge positions of a recorded data pattern is delayed based on the correction values, and recording pulses in NRZI code are formed from the delayed pulse trains. Therefore, it is extremely easy to obtain the recording pulse that is based on the correction values.

[0029] According to the invention described in claim 8, a pulse indicating a front edge position of a recorded data pattern and a pulse indicating a rear edge position thereof are separated by a pulse train separating means, and are delayed, so as to form recording pulses in NRZI code. Therefore, this invention can be used for high speed recording.

[0030] According to the invention described in claim 9, random data of a modulated code that is used serves as the designated data. Therefore, it is possible to determine optimum values that can be used in any user data pattern that is actually recorded.

[0031] According to the invention described in claim 10, a difference between an edge of a reproducing pulse signal and a center of a data identification window is detected. When this difference is large, the correction values are changed by an amount corresponding to this difference, so that optimum values of the recording pulse are determined and set. Therefore, a fine control is possible so that the edge of the reproducing pulse signal is positioned at the center of the window formed by the reproducing system data PLL.

[0032] According to the invention described in claim 11, a plurality of discriminators are used as the edge displacement amount detecting means, and a plurality of reproducing pulse signals are reproduced using a window that is shifted constantly by a predetermined amount as a data identification window corresponding to these discriminators. A verify check is performed on the signals, so that the displacement amount from the center of the data identification window is detected. Therefore, it is possible to detect the edge displacement amount of the reproducing pulse signal with a simple configuration.

[0033] According to the invention described in claim 12, one discriminator is used as the edge displacement amount detecting means, and designated data in which data with the same pattern is repeated is recorded. Subsequently, the data is reproduced while the data identification window is constantly shifted by a predetermined amount. Then, a verify check is performed on the data, so that the displacement amount from the center of the data identification window is detected. Therefore, it is possible to detect the edge displacement amount of the reproducing pulse signal with a circuit of a very small scale.

[0034] According to the invention described in claim 13, a phase comparator is used as the edge displacement amount detecting means. Therefore, it is possible to detect the edge displacement amount of the reproducing pulse signal accurately with an extremely simple configuration.

[0035] According to the invention described in claim 14, similarly to the invention described in claim 3, the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance. Therefore, it is not necessary to store the correction values in the control system on which the CPU is mounted, so that the memory capacity in the control system can be smaller. Furthermore, since it becomes possible to use the initial correction values that are suitable for individual optical recording media, the learning operation time can be shortened. In addition to this, similarly to the invention described in claim 4, the optimum correction values that are determined by the learning function are recorded onto the designated region of the optical recording medium, and are used as initial values in a next leaning operation of correction values. Therefore the learning operation time can be further shortened in the next recording.

[0036]

[Working Examples] A first working example of the present invention will be described with reference to FIG. 1 or FIG. 4. By a learning function, this working example adapts itself to changes of types, characteristics, and ambient environments of an optical recording medium, and changes over time of a driving device and the medium itself, and then determines and sets the optimum correction values of a recording pulse. Then, based on these correction values, an output timing of the recording pulse, a pulse width, and recording power at a leading portion of the recording pulse are corrected, so that edge positions of a recording mark can be controlled accurately.

[0037] For example, when recorded data is written using the mark edge recording system, if the data is converted into NRZI code (non return to zero inverted code) and is used without corrections, the written recorded mark becomes longer than the ideal state as described above (shown as the actually recorded mark also in the upper portion of FIG. 2). Therefore, in

the working example, the edges of the recording mark are controlled to be at the ideal positions, by correcting the pulse width and the output timing of the recording pulse based on the correction values, and by using this corrected recording pulse.

[0038] Furthermore, when the recording mark shape is very irregular as described above in some types of optical recording media, as shown in FIG. 3, the edge positions and the mark shape of the recording mark can be corrected by correcting not only the pulse width and the output timing of the recording pulse, but also the recording power at the leading portion of the recording pulse and the time during which this recording power is changed.

[0039] As these correction values for correcting the recording pulse, correction values of the recording pulse that are suitable for various conditions at that time with respect to the optical recording medium can be used. In this working example, the optimum correction values of the recording pulse for this are determined and set by the learning function of the algorithm shown in FIG. 1.

[0040] First, a CPU writes the initial correction values of the recording pulse into a RAM (memory). Then, predetermined designated data is written and recorded onto an optical recording medium (disk). At that time, a recording pulse of the designated data is corrected based on the correction values that are read from the RAM, and then is written and recorded. Subsequently, this recorded data is reproduced from the disk and the reproduction data is compared with the designated data. As a result of the comparison, when both data match each other, the learning operation is ended as the correction values are appropriate. On the other hand, when both data do not match each other, the correction values that have been read from the RAM are changed and written again into the RAM. Then, the recording pulse of the designated data is corrected based on these changed correction values and the designated data is written and recorded onto the disk. The recorded data is reproduced and the reproduction data is

compared with the designated data. This procedure is repeated until both data match each other. The correction values of the time when both data match each other are stored into the RAM as the optimum correction values for the disk conditions at that time.

[0041] As concrete data for the correction values, output timings of front and rear edges of the recording pulse or the like may be used (these two output timings determine the pulse width). Furthermore, if correction values of the recording power at the leading portion of the recording pulse and the time during which this recording power is changed are also stored, it is possible to correct the recording mark shape.

[0042] A mark edge recording apparatus with such a learning function may be configured as shown in FIG. 4, for example. First, a controller 1 including a CPU and the like is provided. A RAM (memory) 2, and a writing system 4 and a reproducing system 5 corresponding to an optical disk (an optical recording medium) 3 are connected to this controller 1. A selector 6 for switching between writing/reading operations is connected to the RAM 2. The writing system 4 is provided with a modulator 7 that converts the designated data from the controller 1 into a modulated code, a recording pulse correcting means 8 that corrects the modulated code based on the correction values read out from the RAM 2, and a laser driving circuit 9 that is driven based on the corrected recording pulse. In this writing system, writing operations onto the optical disk 3 are performed through an optical pick-up 10.

[0043] On the other hand, the reproducing system 5 is provided with a reproduction amplifier 11 that amplifies the detected signal detected by the optical pick-up 10 from the optical disk 3, a waveform equalizer 12 that shapes the waveform of the signal, and a binarizing circuit 13 that binarizes the signal. In the reproducing system, this signal is reproduced as reproduction data through a discriminator/demodulator 14. In parallel with the discriminator/demodulator 14, a reproducing system data PLL

(phase locked loop) 15 is provided, and a synchronization signal is given to the discriminator/demodulator 14.

[0044] In this configuration, first, the CPU in the controller 1 writes the initial correction values of the recording pulse into the RAM 2 in advance. When the initial correction values or changed correction values as described below are written into the RAM 2, the RAM 2 is set to the writing mode by a selection signal from the controller 1, and the data of the correction values is written into the RAM 2. At all other times, the RAM 2 is set to the reading mode, so that the correction values can be read out from the RAM 2 to the recording pulse correcting means 8 when needed.

[0045] Subsequently, predetermined designated data is written and recorded onto the optical disk 3. This designated data is sent from the controller 1 and is converted into a modulated code by the modulator 7. As a modulating system, any system can be used. For example, (2, 7) RLL code (run length limited code), (1, 7) RLL code, or the like can be used. The modulated data modulated in this manner is converted into the corrected recording pulse by the recording pulse correcting means 8. Herein, the correction values of the recording pulse is read out from the RAM 2, based on which the pulse width, the output timing, and the recording power at the leading portion of the recording pulse and the like are corrected. When the corrected recording pulse is output to the laser driving circuit 9, the laser emits light pulses, so that recording marks are written and formed on the optical disk 3 through the optical pick-up 10, and thus recording is performed.

[0046] After the designated data is written and recorded in this manner, the recorded data is reproduced in the reproducing system 5. This reproducing system 5 is configured similarly to reproducing systems in ordinal driving devices. First, the detected signal that is detected by optical pick-up 10 is amplified by the reproduction amplifier 11, its waveform is shaped by the waveform equalizer 12, and is binarized by the binarizing circuit 13. This

binarized reproducing pulse signal is given to the discriminator/demodulator 14 and the reproducing system data PLL 15. A synchronization signal that is synchronized with the fundamental cycle of the reproducing pulse signal is given from the reproducing system data PLL 15 to the discriminator/demodulator 14, so that it is detected whether or not the reproducing pulse signal is positioned within a data identification window that is formed by the synchronization signal, and the reproducing pulse signal is demodulated as reproduction data. This reproduction data that has been demodulated is sent to the controller 1 and is compared with the designated data. As a result of this comparison, when both data match each other, the learning operation is ended. When both data do not match each other, the correction values are changed and are written again by the CPU in the controller 1 into the RAM 2. The above-described learning operation is repeated until errors are eliminated in the reproduction data, that is, until the reproduction data matches the designated data.

[0047] It should be noted that actual recording of data may be performed similarly to the case of recording the designated data.

[0048] Next, a second working example of the present invention will be described with reference to FIG. 5 or FIG. 7. Similarly to the previous working example, this working example basically repeats the learning operation of the correction values until the reproduction data matches the designated data. In addition to this, after both data match each other, this working example shifts the phase of the reproducing system data PLL 15, reproduces the recorded data, and then compares the reproduction data with the designated data. This procedure is repeated until both data match each other, so that the learning operation of the correction values is performed more completely.

[0049] FIG. 5 shows an algorithm of this learning operation. After both data obtained by the operation of the previous working example match each other (the result of a verify check is "OK"), the phase of the reproducing

system data PLL 15 is shifted appropriately, and then the recorded data on the optical disk 3 is reproduced. This reproduction data is compared with the designated data, and when they match each other, the learning operation is ended. When they do not match each other, similarly to the previous example, the correction values are changed and written again into the RAM 2. Then, the above operation is performed again. The above operation is repeated until the reproduction data as a result of shifting the phase of the reproducing system data PLL 15 matches the designated data. The correction values of the time when both data match each other are stored and set in the RAM 2 as the optimum values.

[0050] In order to realize the working example, it is not necessary to change the configuration drastically. It suffices if a PLL phase control signal can be sent from the controller 1 to the reproducing system data PLL 15 after the learning operation of the previous working example as shown in FIG. 6, to shift the phase of the reproducing system data PLL 15.

[0051] Hereinafter, an effect of the working example is described with reference to a timing chart shown in FIG. 7. In FIG. 7, as shown in portion A, when the edge of the reproducing pulse signal is not positioned near the center of the data identification window that is formed based on the synchronization signal of the reproducing system data PLL 15, an error occurs in the reproduction data if the window shifts back and forth. FIG. 7 shows a case in which the window shifts forward. Therefore, this working example determines the correction values of the recording pulse with which a data error does not occur as shown in portion B even when the phase of the reproducing system data PLL 15 is shifted and the window shifts back and forth. These correction values are stored and set as the optimum values. For ease of understanding, in FIG. 7, the window is set to open only when the reproducing pulse signal is 1.

[0052] Furthermore, a third working example of the present invention will be described with reference to FIG. 8. This working example can be used

when the displacement amount of the edge position varies depending on the recorded data pattern. The correction values corresponding to the recorded data pattern are set, and then the recording pulse is corrected, so that the edge positions and the mark shape can be controlled accurately.

[0053] First, a data pattern identification means 16 is provided that identifies a data pattern of modulated data modulated by the modulator 7 when the designated data (or actual data) is written. This data pattern identification means 16 determines a recording pulse length L_0 that is to be actually written, a blank length L_1 right before this recording pulse, and a recording pulse length L_2 before this blank, as shown in FIG. 2 and FIG. 3. The length values L_0, L_1, and L2 are input into the RAM 2 as its address. An output from this RAM 2 is set to the correction values of the recording pulse corresponding to the recorded data pattern, and the correction values are given to the recording pulse correcting means 8. Since the initial address information is given from the controller 1 to the RAM 2, a selector 17 is interposed on the address inputting side of the RAM 2. That is to say, when the initial correction values or changed correction values are written into the RAM 2, a selection signal from the controller 1 via the selectors 6 and 17 sets the RAM 2 to the writing mode, and the data information of the correction values is written into the RAM 2. At all other times, the RAM 2 is set to the reading mode. The length values L_0, L_1, and L2 are input into the RAM 2 as its address. An output of the address from this RAM 2 is set to the correction values of the recording pulse corresponding to the recorded data pattern, and the correction values are sent to the recording pulse correcting means 8.

[0054] Next, a fourth working example of the present invention will be described with reference to FIG. 9. This working example has an improved configuration of the recording pulse correcting means 8, in which a delaying means 20 including a delaying element 18 and a selector 19 is longitudinally connected to a toggle type flip-flop 21, and operations are controlled with the

correction values of the recording pulse from the RAM 2 as the selection signals.

[0055] First, in the modulated data, the front edge pulse determining the leading portion of the recording pulse and the rear edge pulse determining the trailing portion of the recording pulse are disposed alternately. When the modulated data is input into the toggle type flip-flop 21, the data is converted into NRZI code, and then is output as a recording pulse. Therefore, when the designated data (or actual data) is recorded, these pulses are delayed by the delaying element 18 and are input into the selector 19 so that one among them is selected, while the correction value data obtained from the RAM 2 is used as the selection signal. In order to shorten the recording pulse width, the rear edge pulse needs to be moved forward. However, this working example delays front and rear edge pulses by receiving the modulated data earlier by a predetermined time, since there is no element that moves the pulses forward. When a pulse train that is delayed based on these correction value data is input into the toggle type flip-flop 21, the toggle type flip-flop 21 outputs a recording pulse that is corrected in accordance with the recorded data pattern.

[0056] Next, a fifth working example of the present invention will be described with reference to FIG. 10. The recording pulse correcting means 8 of this working example is provided with a demultiplexer 22 serving as a pulse train separating means for separating the input modulated data into the front edge pulse determining the leading portion of the recording pulse and the rear edge pulse determining the trailing portion of the recording pulse. Following this demultiplexer 22, a delaying element 24 and a selector 25 are provided as a front edge pulse delaying means 23. Furthermore, a delaying element 27 and a selector 28 are provided as a rear edge pulse delaying means 26. Among the correction value data in the RAM 2, a selection signal for front edge pulse delaying data is given to the selector 25. One of the front edge pulses that are delayed by the delaying

element 24 is selected by the selector 25. Similarly, among the correction value data in the RAM 2, a selection signal for rear edge pulse delaying data is given to the selector 28. One of the rear edge pulses that are delayed by the delaying element 27 is selected by the selector 28. An SR flip-flop 29 is provided, which serves as a generation means through which the selector 25 outputs a set signal and the selector 28 outputs a reset signal. Therefore, this SR flip-flop 29 outputs a recording pulse that is corrected in accordance with the recorded data pattern.

[0057] In this working example, the front edge pulse and the rear edge pulse are separated, and then a delaying process and a generation process of the recording pulse in NRZI code are performed, so that this example can be used for high speed recording.

[0058] Next, a sixth working example of the present invention will be described with reference to FIG. 11. In this working example, the above-described initial correction values of the recording pulse are stored in a designated region of the optical disk 3 in advance. Then, the initial values of the correction value data that are read from this designated region are written into the RAM 2, so that the above-described learning operation is performed. As the designated region of the optical disk 3, for example, a SFP (standard formatted part) or the like is used.

[0059] In this working example, individual optical disks 3 retain their suitable correction values as initial values, so that the learning operation time of the optical disks 3 can be shortened.

[0060] Furthermore, if the optimum correction values that are determined by the learning operation are recorded over the initial values that are stored in the designated region at that time, and are used as the initial values in the next learning operation, the learning operation time in the next recording can be shortened further.

[0061] A seventh working example of the present invention will be described with reference to FIG. 12 or FIG. 14. This working example is provided

with the above-described system of the third working example. More specifically, as shown in FIG. 8, when the designated data (or actual data) is written, the recording pulse length L_0 that is to be actually written, the blank length L_1 right before this recording pulse, and the recording pulse length L_2 before this blank are respectively determined by the data pattern identification means 16, as data patterns for the modulated data that is modulated by the modulator 7.

[0062] An algorithm of the learning operation according to this working example will be described with reference to FIG. 12. First, the CPU writes the initial correction values of the recording pulse into the RAM 2. Then the predetermined designated data is written onto the optical disk 3. At that time, similarly to the above-described case, the recording pulse length L_0 that is to be actually written, the blank length L_1 right before this recording pulse, and the recording pulse length L_2 before this blank are respectively determined. The correction values that correspond to these length values L_0, L_1, and L2 are set by the RAM 2, and based on these correction values, the recording pulse is corrected and recorded onto the optical disk 3. Subsequently, the designated data that has been recorded is reproduced, and the difference between the edge of the obtained reproducing pulse signal and the center of the data identification window (the displacement amount) is detected. When this difference is not larger than a predetermined value, the learning operation is ended (this corresponds the process of the above-described working example). However, when the difference is larger than the predetermined value, the correction value data is changed to the amount corresponding to this difference, and is written again into the RAM 2. Simultaneously, a verify check to determine whether or not the reproduction data matches the designated data is performed. When the edge positions are shifted excessively and data errors occur, the correction value data is further changed and written again into the RAM 2. The above operation is repeated until the edge of the reproducing pulse

signal is moved substantially to the center of the data identification window, so that the optimum correction values of the recording pulse are determined and set.

[0063] Due to this learning operation, the optimum correction values of the recoding pulse for conditions of the optical disk 3 at that time are written into the RAM 2. Then, the recording pulse is corrected using these optimum correction values, and the data is recorded. Thus, the edge position control can be performed accurately, which is suitable for various conditions at that time, and which can be used in changes of types and characteristics of the optical disk 3, changes in the ambient environment, and changes over time of a driving device and the disk.

[0064] It is also possible to follow the following procedure. First, the initial correction values of the recording pulse are not written into the RAM 2. The designated data is recorded onto the optical disk 3 without corrections. Then, the designated data is reproduced, and the difference between the edge of the reproducing pulse signal and the center of the data identification window (the displacement amount) is detected. Subsequently, the amount corresponding to the difference is determined and set as the optimum correction values. Thus, even when the initial correction values are not clear, the optimum correction values can be determined by the above-described learning operation. Furthermore, it is not necessary to store the initial correction values in the controller 1.

[0065] A mark edge recording apparatus with such a learning function may be configured as shown in FIG. 13, for example. In other words, in addition to the configurations shown in FIG. 4 (or FIG. 6) and FIG. 8, on the side of the reproducing system 5, an edge displacement amount detecting means 30 is provided in connection to a discriminator 14a (herein, the discriminator/demodulator 14 is shown separately as the discriminator 14a and a demodulator 14b) for detecting whether or not the edge of the reproducing pulse signal is positioned within the data identification window

formed based on the synchronization signal from the reproducing system data PLL 15, and then the detected data of the edge displacement amount is fetched into the CPU in the controller 1.

[0066] In this configuration, the writing system 4 performs its process similarly to that in the above-described working example. On the other hand, the operation of the reproducing system 5 will be described with reference to FIG. 14. As shown in FIG. 14, when the edge positions of the written recording mark are shifted excessively, the edges of the reproducing pulse signal are also shifted excessively to outside of the data identification window, and thus data errors may occur. When the edges of the reproducing pulse signal are not positioned near the center of the data identification window, data errors may occur if the window shifts back and forth. Therefore, in the working example, the edge displacement amount detecting means 30 detects the difference between the edge of the reproducing pulse signal and the center of the data identification window, that is, the edge displacement amount of the reproducing pulse signal. Then, the amount corresponding to the difference is added to or subtracted from the correction values that are stored in the RAM 2 at that time, and the obtained values are written again into the RAM 2 as the optimum correction values. Through the above operation, the optimum correction values of the recording pulse can be determined and set accurately, so that the edges of the reproducing pulse signal are positioned at the center of the data identification window so as not to cause a data error even when the data identification window shifts back and forth. For the sake of simplicity, in the example shown in FIG. 14, the window opens only when the reproduction data is “1.”

[0067] When data is actually written onto the optical disk 3, in a similar manner in which the designated data is recorded, the correction values corresponding to the recorded data pattern are set by the RAM 2, and then, according to these, the recording pulse may be corrected and recorded.

[0068] It should be noted that when the edge displacement amount detecting means 30 is provided with a phase comparator in FIG. 13, it is possible to detect the edge displacement amount of the reproducing pulse signal accurately with an extremely simple configuration.

[0069] Furthermore, an eighth working example of the present invention will be described with reference to FIG. 15 and FIG. 16. In this working example, an edge displacement amount detecting means 31 is provided with a plurality of discriminators $14a_1$ to $14a_n$ and demodulators $14b_1$ to $14b_n$ corresponding to the discriminators $14a_1$ to $14a_n$. Thus, the reproducing pulse signals are detected respectively, using a plurality of data identification windows 1 to n that shift by a predetermined amount as data identification windows of these discriminators $14a_1$ to $14a_n$. Then, the signals are demodulated as reproduction data 1 to n. With a result of a verify check on the reproduction data, it can be detected to what amount the edge of the reproducing pulse signal is shifted from the center of the original window 1.

[0070] In the example shown in FIG. 16, an error does not occur in the reproduction data discriminated by the windows 1 and 2, while an error occurs in the reproduction data discriminated by the windows 3 to n. Therefore, the edge of the reproducing pulse signal is positioned within a region 2 of the original window 1. Thus, it is possible to detect the difference between the edge of the reproducing pulse signal and the center of the data identification window 1. As actual reproduction data, reproduction data 1 that is obtained through the discriminator $14a_1$ and the demodulator $14b_1$ is used.

[0071] The learning operation may follow the following procedure. When the designated data is recorded in the learning operation, the designated data in which the same pattern is repeated is recorded. During reproduction, one discriminator discriminates the data while constantly shifting the data identification window by a certain amount. With a result

of a verify check on the reproduction data, it is detected to what extent the edge of the reproducing pulse signal is shifted from the center of the original data identification window 1. In FIG. 16, the reproducing pulse signal in which the same pattern is repeated a plurality of times is reproduced while constantly changing the data identification window from 1 to n, and it is detected in which region of the original window 1 the edge of the reproducing pulse signal is positioned. Thus, the difference between the edge of the recording pulse signal and the center of the original window 1 is detected.

[0072] In systems considering the edge displacement amount as described in the seventh and the eighth working example, the learning operation time may be shortened by a system such as shown in FIG. 11. That is, the initial correction values of the recording pulse is stored in the designated region of the optical disk 3 in advance. Then the initial correction values read from this designated region are written into the RAM 2, so that the above-described learning operation is performed. Furthermore, the optimum correction values determined by the learning operation are recorded over the initial values stored in the designated region at that time, and are used as the initial correction values in the next learning operation, so that the learning operation time in the next recording can be further shortened.

[0073] In these working examples, random data of the modulated code that is used serves as the designated data.

[0074] The above-described learning operation is performed when switching on, before recording data, or during an idle time of the driving device, so as not to impede other operations of the driving device.

[0075]

[Effect of the Invention] According to the invention described in claim 1, in a mark edge recording system, A CPU writes initial correction values of a pulse width and an output timing of a recording pulse into a memory. A

recording pulse of designated data is written and recorded onto the optical recording medium based on the correction values that are stored in the memory, after which the recorded data is reproduced. The reproduction data is compared with the designated data. The correction values are repeatedly changed and written into the memory, written/recorded onto the optical recording medium based on the correction values, and reproduced/compared until both data match each other, so that optimum correction values are determined and set. Due to this learning function, the edge position control can be performed appropriately, so that it is possible to accommodate changes in the type or the characteristics of the optical recording medium at that time, changes in the ambient environment, and changes over time of a driving device or the medium itself.

[0076] In addition to the above, according to the invention described in claim 2, after the reproduction data matches the designated data, the recorded data is reproduced again while shifting a phase of a reproducing system data PLL by a predetermined amount. The reproduction data is compared with the designated data. Until both data match each other, the correction values are again repeatedly changed and written into the memory, written/recorded onto the optical recording medium based on the correction values, and reproduced/compared. After both data match each other, the correction values are repeatedly reproduced/compared while shifting the phase, so that optimum correction values are determined and set. Due to this additional learning function, it becomes possible to correct the front and rear edges of the recording pulse so that they are positioned at the center of the data identification window that is formed by the reproducing system data PLL. Thus, the edge positions can be controlled further accurately, so that data can be reproduced without an data error even when the phase of the reproducing system data PLL is shifted.

[0077] In addition to these inventions, according to the invention described in claim 3, the initial correction values of the recording pulse are recorded

onto a designated region of the optical recording medium in advance. Therefore, it is not necessary to store the correction values in a control system on which the CPU is mounted, so that the memory capacity in the control system can be smaller. Furthermore, since it becomes possible to use the initial correction values that are suitable for individual optical recording media, the learning operation time can be shortened.

[0078] Furthermore, according to the invention described in claim 4, the determined optimum correction values are recorded onto the designated region of the optical recording medium over the initial values that are stored at that time. The determined optimum correction values serve as initial values in a next leaning operation of correction values. Therefore, the learning operation starts with the more appropriate initial values, so that the learning operation time can be shortened in the next recording.

[0079] Furthermore, according to the invention described in claim 5, the correction values of the recording pulse include not only correction values of a pulse width and an output timing of the recording pulse, but also correction values of recording power at a leading portion of the recording pulse and a time during which this recording power is changed. Therefore, the edge positions and the mark shape of the recording marks can be controlled accurately so as to meet various conditions of the optical recording medium at that time.

[0080] On the other hand, according to the invention described in claim 6, when recording the designated data or actual data, a recording pulse length L_0 that is to be written, a blank length L_1 right before this recording pulse, and a recording pulse length L_2 before this blank are determined by a data pattern identification means. Data of the length values L_0, L_1, and L2 are taken as the address input of the memory. An output from the memory serves as correction values of the recording pulse. Therefore, the correction can be used for recorded data patterns, in addition to changes of types of the optical recording medium, changes in the ambient environment, and changes

over time of a driving device and the medium itself, so that the edge positions can be controlled further accurately.

[0081] In addition to the above, according to the invention described in claim 7, a pulse indicating front and rear edge positions of a recorded data pattern is delayed by a delaying means based on the correction values of the recording pulse that is read out from the memory. From the delayed pulse trains, recording pulses in NRZI code are formed. Therefore, it is extremely easy to obtain the recording pulse that is based on the correction values.

[0082] Similarly, according to the invention described in claim 8, a pulse indicating a front edge position of a recorded data pattern and a pulse indicating a rear edge position thereof are separated by a pulse train separating means, and are delayed, so as to form recording pulses in NRZI code. Therefore, this invention can be used for high speed recording.

[0083] According to the invention described in claim 9, random data of a modulated code that is used serves as the designated data. Therefore, it is possible to determine optimum values that can be used in any user data pattern that is actually recorded.

[0084] On the other hand, according to the invention described in claim 10, a difference between an edge of a reproducing pulse signal and a center of a data identification window is detected. When this difference is large, the correction values are changed by an amount corresponding to this difference, so that optimum values of the recording pulse are determined and set. Therefore, a fine control is possible so that the edge of the reproducing pulse signal is positioned at the center of the window formed by the reproducing system data PLL.

[0085] At that time, according to the invention described in claim 11, a plurality of discriminators are used as the edge displacement amount detecting means, and a plurality of reproducing pulse signals are reproduced using a window that is shifted constantly by a predetermined amount as a data identification window corresponding to these discriminators. A verify

check is performed on the signals, so that the displacement amount from the center of the data identification window is detected. Therefore, it is possible to detect the edge displacement amount of the reproducing pulse signal with a simple configuration.

[0086] Furthermore, according to the invention described in claim 12, one discriminator is used as the edge displacement amount detecting means, and designated data in which data with the same pattern is repeated is recorded. Subsequently, the data is reproduced while the data identification window is constantly shifted by a predetermined amount. Then, a verify check is performed on the data, so that the displacement amount from the center of the data identification window is detected. Therefore, it is possible to detect the edge displacement amount of the reproducing pulse signal with a circuit of a very small scale.

[0087] On the other hand, according to the invention described in claim 13, a phase comparator is used as the edge displacement amount detecting means. Therefore, it is possible to detect the edge displacement amount of the reproducing pulse signal accurately with an extremely simple configuration.

[0088] Furthermore, according to the invention described in claim 14, similarly to the invention described in claim 3, the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance. Therefore, it is not necessary to store the correction values in the control system on which the CPU is mounted, so that the memory capacity in the control system can be smaller. Furthermore, since it becomes possible to use the initial correction values that are suitable for individual optical recording media, the learning operation time can be shortened. In addition to this, similarly to the invention described in claim 4, the optimum correction values that are determined by the learning function are recorded onto the designated region of the optical recording medium, and are used as initial values in a next leaning operation of correction values. Therefore the learning operation time can be further

shortened in the next recording.

[Brief Description of the Drawings]

[FIG. 1] A flow chart illustrating a first working example according to the present invention.

[FIG. 2] A diagram illustrating an example of a recording pulse correcting method.

[FIG. 3] A diagram illustrating another example of the recording pulse correcting method.

[FIG. 4] A block diagram.

[FIG. 5] A flow chart illustrating a second working example according to the invention.

[FIG. 6] A block diagram.

[FIG. 7] A timing chart for explaining its operation.

[FIG. 8] A block diagram illustrating a third working example according to the invention.

[FIG. 9] A block diagram illustrating a fourth working example according to the invention.

[FIG. 10] A block diagram illustrating a fifth working example according to the invention.

[FIG. 11] A flow chart illustrating a sixth working example according to the invention.

[FIG. 12] A flow chart illustrating a seventh working example according to the invention.

[FIG. 13] A block diagram illustrating its configuration.

[FIG. 14] A timing chart for explaining its operation.

[FIG. 15] A block diagram illustrating an eighth working example according to the invention.

[FIG. 16] A timing chart for explaining its operation.

[FIG. 17] A diagram illustrating an irregular shape of a recording mark

recording mark according to a conventional method.

[FIG. 18] An explanatory drawing illustrating a displacement of edge positions according to a conventional method.

[Description of symbols]

2	memory
3	optical recording medium
$14a_1$ to $14a_n$	discriminator
16	recorded data pattern identification means
20	delaying means
22	pulse train separating means
23	delaying means
26	delaying means
30, 31	edge displacement amount detecting means

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[Amendment 1]

[Name of Document to be Amended] Specification

[Name of Item to be Amended] Claim 10

[Manner of Amendment] Modification

[Contents of Amendment]

[Claim 10] The recording pulse correcting method for the mark edge recording system according to claim 6,

wherein a displacement amount of an edge of a reproducing pulse signal <u>from a reproduction clock</u> is detected by an edge displacement amount

detecting means; and

wherein <u>in accordance with</u> this displacement amount, optimum correction values <u>of the recording pulse</u> are determined and set.

[Amendment 2]

[Name of Document to be Amended] Specification

[Name of Item to be Amended] Claim 14

[Manner of Amendment] Modification

[Contents of Amendment]

[Claim 14]

The recording pulse correcting method for the mark edge recording system according to claim 10,

wherein the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance,

wherein the initial correction values of the recording pulse <u>that are read out</u> from the designated region of the optical recording medium are written into the memory,

wherein determined optimum correction values are written over the initial values that are stored in the designated region of the optical recording medium at that time, and

wherein the determined optimum correction values serve as initial values in a next learning operation of correction values.

[Amendment 3]

[Name of Document to be Amended] Specification

[Name of Item to be Amended] 0017

[Manner of Amendment] Modification

[Contents of Amendment]

[0017] According to the invention described in claim 10, in addition

to the invention described in claim 6, a displacement amount of an edge of a reproducing pulse signal from a reproduction clock is detected by an edge displacement amount detecting means. In accordance with this displacement amount, optimum correction values of the recording pulse are determined and set.

[Amendment 4]

[Name of Document to be Amended]	Specification
[Name of Item to be Amended]	0021
[Manner of Amendment]	Modification

[Contents of Amendment]

[0021] Furthermore, according to the invention described in claim 14, the initial correction values of the recording pulse are recorded onto a designated region of the optical recording medium in advance. The initial correction values of the recording pulse that are read out from the designated region of the optical recording medium are written into the memory. Determined optimum correction values are written over the initial values that are stored in the designated region of the optical recording medium at that time. The determined optimum correction values serve as initial values in a next learning operation of correction values.

[Amendment 5]

[Name of Document to be Amended]	Specification
[Name of Item to be Amended]	0031
[Manner of Amendment]	Modification

[Contents of Amendment]

[0031] According to the invention described in claim 10, a displacement amount of a reproducing pulse signal from a reproduction clock is detected. In accordance with this displacement amount, optimum values of the recording pulse are determined and set. Therefore, for example, a

fine control is possible so that the edge of the reproducing pulse signal is positioned at the center of the window formed by the reproducing system data PLL.

[Amendment 6]

[Name of Document to be Amended] Specification

[Name of Item to be Amended] 0084

[Manner of Amendment] Modification

[Contents of Amendment]

[0084] On the other hand, according to the invention described in claim 10, a displacement amount of a reproducing pulse signal from a reproduction clock is detected. In accordance with this displacement amount, optimum values of the recording pulse are determined and set. Therefore, for example, a fine control is possible so that the edge of the reproducing pulse signal is positioned at the center of the window formed by the reproducing system data PLL.

[Translation Japanese → English of JP H06-052547A]

Drawings

FIG. 1

start

write initial correction values into RAM

record designated data onto disk

reproduce above recorded data

error in verify check?

change correction values and write again into RAM

end

FIG. 2

modulated data

uncorrected recording pulse (NRZI code)

actually recorded mark

corrected recording pulse

recording mark

FIG. 3

modulated data

uncorrected recording pulse (NRZI code)

actually recorded mark

corrected recording pulse

recording mark

FIG. 4

1 controller

2 RAM

6 selector

7 modulator
8 recording pulse correcting means
9 laser driving circuit
10 optical pick-up
11 reproduction amplifier
12 waveform equalizer
13 binarizing circuit
14 discriminator/demodulator
15 PLL
designated data
modulated data
corrected recording pulse
address information of correction values
selection signal
correction values
data information of correction values
detected signal
reproducing pulse signal
synchronization signal
reproduction data

FIG. 5

start
write initial correction values into RAM
record designated data onto disk
reproduce above recorded data
error in verify check?
displace reproducing system data PLL
reproduce recorded data
error in verify check?

change correction values and write again into RAM
end

FIG. 6

1	controller
2	RAM
6	selector
7	modulator
8	recording pulse correcting means
9	laser driving circuit
10	optical pick-up
11	reproduction amplifier
12	waveform equalizer
13	binarizing circuit
14	discriminator/demodulator
15	PLL

designated data
modulated data
corrected recording pulse
address information of correction values
selection signal
correction values
data information of correction values
detected signal
reproducing pulse signal
PLL phase control signal
synchronization signal
reproduction data

FIG. 7

recorded data

reproducing pulse signal

data identification window

center

shift forward

shift backward

error

FIG. 8

2	RAM
6	selector
8	recording pulse correcting means
16	recorded data pattern identification means
17	selector

modulated data

corrected recording pulse

correction values

(from controller)

correction values address information

selection signal

data information of correction values

FIG. 9

18	delaying element
19	selector
20	delaying means
21	T-F/F

modulated data

recording pulse correction values

selection signal

corrected recording pulse

FIG. 10

22 demultiplexer
23 delaying means
24 delaying element
25 selector
26 delaying means
27 delaying element
28 selector
29 SR-F/F
modulated data
front edge pulse
front edge pulse delaying data
selection signal
rear edge pulse
rear edge pulse delaying data
selection signal
corrected recording pulse

FIG. 11

start
read initial correction values from disk
write initial correction values into RAM
learning operation

FIG. 12

start
write initial correction values into RAM
record designated data onto disk

reproduce above recorded data
detect edge displacement amount of reproducing pulse
is edge displacement amount below predetermined value?
change correction values to extent of edge displacement amount
write changed correction values into RAM

FIG. 13

1	controller
2	RAM
6	selector
7	modulator
8	recording pulse correcting means
9	laser driving circuit
10	optical pick-up
11	reproduction amplifier
12	waveform equalizer
13	binarizing circuit
14b	demodulator
15	PLL
16	recorded data pattern identification means
17	selector
30	edge displacement amount detecting means

designated data
modulated data
L_0, L_1, and L_2
address information of correction values
address
correction values
selection signal
data information of correction values

detected signal
reproducing pulse signal
synchronization signal
window
edge displacement amount
reproduction data

FIG. 14
recorded data
recording mark
reproducing pulse signal
window
displacement amount
reproduction data
data error
shifted window
reproduction data
data error
data error

FIG. 15
1 controller
$14a_1$ discriminator
$14a_2$ discriminator
$14a_n$ discriminator
$14b_1$ demodulator
$14b_2$ demodulator
$14b_n$ demodulator
15 PLL
reproducing pulse signal

window 1
window 2
window n
reproduction data 1
reproduction data 2
reproduction data n

FIG. 16
reproducing pulse signal
data identification window 1
data identification window 2
data identification window 3
data identification window n
region 1, 2, ... n
center of window 1

FIG. 17
recording pulse
actually recorded mark

FIG. 18
data pattern a
actually recorded mark
data pattern b
actually recorded mark